Vegetation analysis of wetlands in the Klerksdorp Municipal Area, North West Province, South Africa

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Motivation for investigations of urban wetlands lies in the fact that wetlands probably contain some of the most vulnerable plant communities in South Africa. Urban wetlands are also situated in some of the most disturbed environments and are, therefore, desperately in need of a well-formulated management policy. Vegetation information in planning and management programs should be accurate and scientific in terms of floristic detail and actual community distribution. It is, therefore, important to do a comprehensive vegetation analysis of any area before management programs are formulated. Relevès from the Klerksdorp wetlands were processed by TWINSPAN and Braun-Blanquet classification procedures, using the BBPC package, while DECORANA was used to identify gradients in vegetation in correlation with certain habitat parameters. The aim of this study was to classify the vegetation of the wetlands and to identify and characterize the different areas where the disturbances, resulting from human impact, were the highest. A total of nine plant communities, four subcommunities and three variants were described. This study could contribute to compile a guideline for a development and conservation management plan for the area, but also created new knowledge on the reaction of indigenous and ruderal plant species under disturbed conditions in wetlands.

Keywords: Anthropogenic influences, Braun-Blanquet, disturbed areas, phytosociology, invader species, TWINSPAN, urban ecology, wetlands.

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Introduction

Although the vegetation of the western-Transvaal grassland has been broadly classified (Bezuidenhout 1993), until recently little attention was given to the vegetation of wetlands. Studies in wetlands have been done in the Free State by Eckhardt *et al.* (1993), Fuls *et al.* (1992), Kooij *et al.* (1991) and Smit *et al.* (1995). Wetland communities were also described by Bloem *et al.* (1993) in the Verlorenvallei Nature Reserve and by Myburgh *et al.* (1995) in the Grootvlei-Villiers vicinity. Very few studies dealing with the species composition and reaction of wetland vegetation in urban environments were, however, done in South Africa. The only published studies on urban wetlands, that we are aware of, were in the Durban Municipal Area (Roberts 1993a) and in the Potchefstroom Municipal Area (Cilliers *et al.* 1998).

The degradation of wetlands is still continuing, mainly because little is known about the desired condition and conservation status of these areas. According to Fuls *et al.* (1992) the sensitivity and reaction of hydrophilic vegetation, makes wetlands especially vulnerable to degradation and other disturbances. Huge wetland areas have already been destroyed in South Africa and they can probably be regarded as the most endangered ecosystem type in the country (Walmsley 1988). Factors such as the increase in the amount of run-off water, pollution and the disturbance of the natural habitat, which is characteristic of the urban environment (Sukopp & Werner 1983; Aey 1990; Sukopp 1990), contributes to the degradation of wetlands in urban areas. To diminish the impact of urban runoff and waste on natural systems by making them more compatible with the system's tolerance and assimilative capacity is, according to Cairns and Heckman (1996) one of the main aims of the ecological restoration of urban areas. Haslam (1996), however, argued that improving one parameter such as pollution in wetland areas without recreating diverse and abundant plant and animal communities can only be regarded as enhancement and not restoration in the true sense of the word.

Despite the fact that the World Conservation Strategy identifies wetlands as the third most important life support system in the world (Cowan 1995), they were regarded for a long time as areas of little value and use. Because of this negative view, many wetlands have been drained and damaged by agricultural and industrial activities as well as urban development (Archibald & Batchelor 1992). According to Cowan (1995), it was decided at the Ramsar Convention, that wetlands should be sustainably utilised. This should be practiced in a way that is adaptable to the maintenance of the natural qualities of the ecosystem. Human utilisation should be such that, while the wetlands are used in favour of the present generation, they must still have the potential to fulfil the needs and aspirations of future generations (Cowan 1995).

Vegetation studies in urban environments are important to ensure ecological effective open space planning in urban areas (Roberts 1993a). In order to determine condition and conservation status, it is necessary to do an in-depth vegetation analysis of an area. It is also important to explain the distribution of the plant communities in accordance to the existing environmental factors, and to shed some light on the influence of the urban environment and the associated disturbances on the wetlands.

In Europe, information from similar vegetation studies is used as important guide-lines for the management of urban areas (Pyšek 1995). Existing studies in South Africa indicate a need for a new approach for planning and management of open spaces in urban areas (Roberts & Poynton 1985; Roberts 1993a). Poynton and Roberts (1985) stressed the importance of

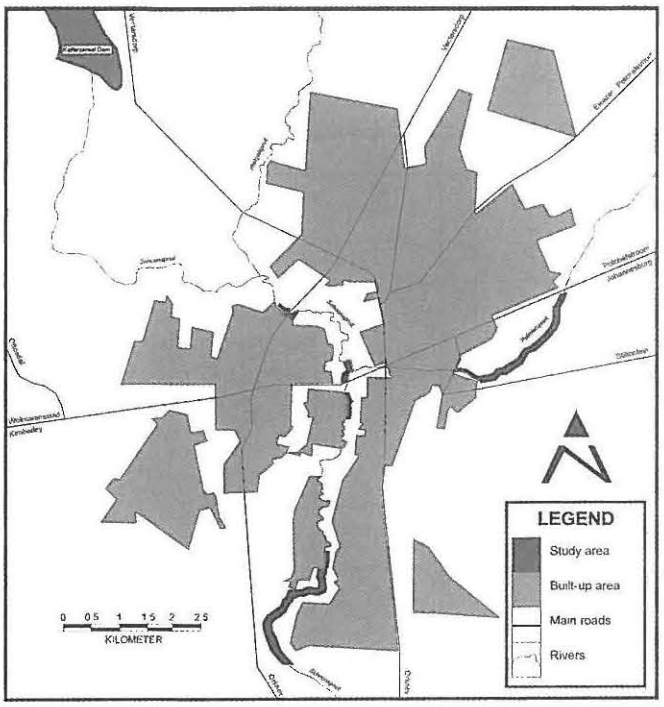

Figure 1 The location of the study area in the Klerksdorp Municipal Area, North West Province, South Africa.

biogeographic guide-lines during planning and management of urban open spaces. The potential of wetlands as dispersal corridors for plants and animals in the urban environment should, therefore, be taken into consideration as they are important to maintain and increase biodiversity in urban areas (Roberts 1993b). Wetlands already form the basis of most Metropolitan Open Space Systems (MOSS) in South Africa (Cooper & Duthie 1992). According to Cross *et al.* (1991) wetland management plans should be based on corridor concepts and the recognition of the dynamic nature of wetland vegetation in response to variations in water regimes. Water dispersal definitely plays a role in structuring riparian flora and explaining species distribution patterns. Continuous river/wetland corridors are also important in the maintenance of regional biodiversity (Johansson *et al.* 1996).

Large parts of South Africa's water catchment areas flow through urban areas. The implications of an unhealthy and disturbed urban wetland, therefore, lies much wider than the borders of the city. The importance of a healthy wetland system in the urban environment is definitely a critical point which deserves more attention. The Department of Water Affairs (1986) regards the presence of harmful, pollutive substances in rivers as a big threat for the survival of water as a natural resource. Urbanisation, industrialisation and urban growth would also lead to an increase in the pollution of water and the resulting degradation of the country's water systems (Coetzee 1995).

The aim of this study was to compile an in-depth vegetation analysis of the wetlands in the Municipal area of Klerksdorp. This study would shed some light on the state of the wetlands and indicate in which ways human impact contributed to the degradation of urban wetlands.

Study area

This study was conducted in representative wetland areas inside the Klerksdorp Municipal Area (Figure 1). The study area included the wetlands of Schoonspruit and the areas drained by the Schoonspruit. For practical reasons, the study was only conducted in public and municipal areas and not on privately owned small holdings. The city of Klerksdorp is situated in the western parts of the South African Highveld in the Grassland Biome (Rutherford & Westfall 1986) and more specifically in the Dry Sandy Highveld Grassland (37) described by Bredenkamp and Van Rooyen (1996). It is situated around 26°50' longitude and 26°40' latitude.

According to the Köppen classification (Schulze & McGee 1978), Klerksdorp has a Bs-climate, meaning a cool dry steppe (arid climate) with summer rains. The average annual rainfall is 645 mm and the average daily temperature measured over a period of 49 years was 25.6°C with a daily minimum of 9.3°C. The mean maximum daily temperature for December and January exceeds 30°C and the mean minimum daily temperature for July is 0.0°C (Weather Bureau 1988).

According to a land type classification system based upon terrain form, soil pattern and climate the study area is situated in the Bc land type (Land Type Survey Staff 1984). The geology of the study area mainly represents the Ventersdorp Supergroup (SACS 1980).

Materials and Methods

The wetlands of the Klerksdorp Municipal Area were stratified into relative homogenous physiographical and physiognomical areas, using 1:10 000 scale aerial photographs. Relevés were compiled in 56 stratified random sample plots in the study area, representative of these homogenous areas. Plot sizes were fixed at 16 m^2 for grassland and 100 m^2 for woody vegetation in accordance to Bredenkamp and Theron (1978). Cover-abundance values of all species present, were given according to the Braun-Blanquet scale, as given by Mueller-Dombois and Ellenberg (1974).

Habitat parameters recorded included aspect, slope, topography, soil form (Soil Classification Work Group 1991) and various soil characteristics determined by both physical and chemical analyses. These included the particle size distribution, soil pH, electrical conductivity, and the quantity of basic cations such as Na^+, Ca^{2+}, K^+ and Mg^{2+}. The presence of standing water and waterlogged soils and the position of the sample plot in the wetland (Figure 2) were also noted to indicate the effect these factors might have on the vegetation. At each sample plot the presence and intensity of direct and indirect human influences, such as mowing, weeding, trampling, overgrazing, chemical pollution and erosion were only qualitatively described, because it is difficult to quantify these influences.

The floristic data were analysed by applying a statistical classification algorithm, TWINSPAN (Hill 1979a) using the BBPC software package (Bezuidenhout *et al.* 1996). Results were subsequently refined by Braun-Blanquet procedures to identify ecologically sound plant communities. The final results were presented in a phytosociological table (Table 1). Species which were recorded only once or twice during the study and have relatively low cover and/or

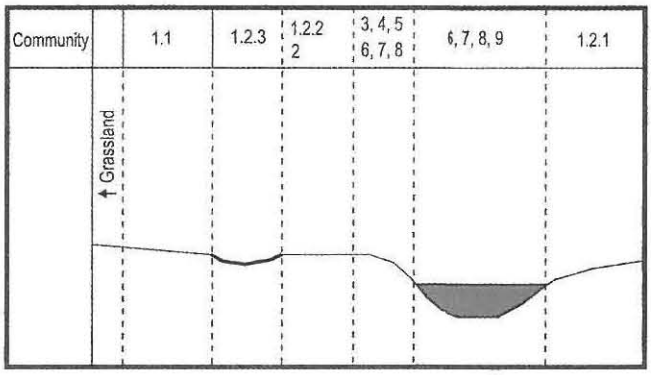

Figure 2 Positions of communities in the wetlands of the Klerksdorp Municipal Area, North West Province, South Africa.

Table 1 A phytosociological table of the wetlands in the Klerksdorp Municipal Area, South Africa

RELEVÉ	17	19	23	33	36	52	47	48	49	56	42	7	8	9	20	15	29	30	55	12	25	26	54	16	32	40	41	1	3	31	34	39	44	2	6	13	14	22	24	28	35	38	50	53	10	18	21	43	37	4	45	46	51	11	5
COMMUNITY	11						121				122					123				2			3			4		5						61							62				7				8						9
SPECIES GROUP A																																																							
Sporobolus africanus	1	1		A		+																								+																									
SPECIES GROUP B																																																							
Hyparrhenia hirta					+	1	r	+	1	1																																		1				1	r						
Rhynchosia totta							+	r	1	r																																													
Xysmalobium undulatum								+	1																																														
_Arundo donax_*							r		r																																											1			
SPECIES GROUP C																																																							
_Cirsium vulgare_* DW			1													1	+		r		r																										1								
Panicum coloratum																	+	r	+	+																																			
Conyza podocephala				+												1			+																																				
SPECIES GROUP D																																																							
_Sesbania bispinosa_*							+	1	A	+	1		+	1		1	1	+	+	1																r	1			1						1	1		+	+					
Senecio inornatus			1				+	r	+	+		1	+		A	1	+		1								r									r	+																		
_Verbena bonariensis_*	r						r	+		r						+		r																				r																	
SPECIES GROUP E																																																							
Themeda triandra	1	A	A	1	A	1	A	r	1	+	+	A	1	+	+	1	A	1	A		+							+		+				+		+		+	+		1		r			+		+							
Setaria sphacelata	A		+	+		1	1	1	A	A	B	A	B	1	+	B	A	B	+							r	+					r	+			+	1	1					r	1			+					+			
Berkheya radula		1	+		1	+	A	1	A	1	+	1	1			+		1	1		+					1	+						1											1				+							
SPECIES GROUP F																																																							
Eragrostis trichophora													r							A	A	+																					+												
Chamaesyce inaequilatera																				+	1	1																																	
Cyperus rupestris																				r	1	r																																	
SPECIES GROUP G																																																							
Cyperus marginatus												1	B	A		1	+	1	B		1	1				r										+		1																	
Anthericum cooperi											+		1	1	+	+	+	r	1	+		+																																	
_Schkuhria pinnata_*					+						1				1		+	+	+		1	1										1							+			+		+			+								
Hypoxis argentea													r	+			+		r	+		r								r																									
Hibiscus trionum											r			+		+						1	+																r						+				r						
SPECIES GROUP H																																																							
_Salix babylonica_*																							B	4	B												1																		
SPECIES GROUP I																																																							
_Eucalyptus camaldulensis_*					+																				A	4	4				1	1			+						1														
Asparagus suaveolens																								+		+	1	+																											
_Bidens pilosa_*																										1	r					r																							
_Ruta graveolens_*																										+	+											r		+						r	+								
SPECIES GROUP J																																																							
_Alternanthera pungens_*	+																											+		r	1	1	+																						
_Gomphrena celosioides_*																												+		+	+		+																						
Chloris virgata																													+		+	+																							
Rhus lancea																														A			1																						
Eragrostis curvula													r								+											+	+																						
Melinis repens																															r		r																						

Table 1 Continued

RELEVÉ	1 1 2 3 3 5 4 4 4 5 4 2 1 2 3 5 1 2 2 5 1 3 4 4 3 3 3 4 1 1 2 2 2 3 3 5 5 1 1 2 4 3 4 4 5 1
	7 9 3 3 6 2 7 8 9 6 2 7 8 9 0 5 9 0 5 2 5 6 4 6 2 0 1 1 3 1 4 9 4 2 6 3 4 2 4 8 5 8 0 3 0 8 1 3 7 4 5 6 1 1 5
COMMUNITY	1.1 1.2.1 1.2.2 1.2.3 2 3 4 5 6.1 6.2 7 8 9
SPECIES GROUP K	
Sida rhombifolia	+ A A + 1 + + 1
*Paspalum dilatatum**	+ + 1 + + + 1 1 1 r + + 1 1 + + + 1
Setaria verticillata	1 + r 1 1 + + + +
Ziziphus mucronata	+ A 1 + + +
SPECIES GROUP L	
Panicum maximum	1 A B A r + 1 A 1 r + +
SPECIES GROUP M	
Paspalum distichum	1 + 1 A + A + A +
*Chenopodium album**	1 1 + 1 1 1 + 1 + +
*Azolla filiculoides**	+ 1 1 + 1 +
*Verbena officinalis**	+ + r + + 1 r 1
*Oenothera rosea**	+ +
*Melilotus alba**	+ 1 r +
Setaria pallide-fusca	+ r
Asclepias fruticosa	+ + + r
SPECIES GROUP N	
Maytenus heterophylla	1 1 + + + + + + + + + 1 + +
*Ipomoea purpurea**	B + 1 1 + + + 1 A + +
*Morus nigra**	+ + 1
SPECIES GROUP O	
*Gleditsia triacanthos**	1 + + A 1 1 1
Urochloa mosambicensis	+ +
SPECIES GROUP P	
Cyperus fastigiatus	+ 1 1 1 + 1 1 1 A A A 3 A B A 1 + + 1 + +
Mariscus congestus	1 + + 1 1 1
*Sesbania punicea** DW	+ 1 A 1 + 1
*Verbena bonariensis**	+ r + + + +
SPECIES GROUP Q	
*Conyza bonariensis**	+ + 1 + 1 1 1 1 + + 1 1 + 1 1 1 + +
*Plantago lanceolata**	r + 1 1 1 1 1 +
Rhus pyroides	1 + 1 A 1 1 1 1
SPECIES GROUP R	
Asparagus laricinus	1 A A 1 A + 1 1 A + 1 1 1 + + 1 1 1 1 1 A 1 1 + 1 1 + +
*Bidens bipinnata**	1 + + 1 + + 1 A 1 + + + + A 1 1 + + +
Cymbopogon plurinodis	+ + + + r + + + + + + r + +
SPECIES GROUP S	
Typha capensis	r + + 3 A 3 A +
*Stenotaphrum secundatum**	+ A 1 +
SPECIES GROUP T	
*Xanthium strumarium**	+ + 1 + r
Persicaria serrulata	+ + + + + + + A r

Table 1: Continued

RELEVÉ	1 1 2 3 3 5 4 4 4 5 4 2 1 2 3 5 1 2 2 5 1 3 4 4 3 3 3 4 1 1 2 2 2 3 3 5 5 1 1 2 4 3 3 4 4 5 1 1
	7 9 3 3 6 2 7 8 9 6 2 7 8 9 0 5 9 0 5 2 5 6 4 6 2 0 1 1 3 1 4 9 4 2 6 3 4 2 4 2 8 5 8 0 3 0 8 1 3 7 4 5 6 1 1 5
COMMUNITY	1 1 1 2 1 1 2 2 3 1 2 3 2 3 4 5 6 1 6 2 7 8 9
SPECIES GROUP U	
*Tagetus minuta**	1 1 1 + r + 1 1 1 + 1 1 1 A B 1 + 1 + 1 1 3 + A 1 1 1 1
SPECIES GROUP V	
Cynodon dactylon	1 A A B + + 1 1 + + A + 1 1 1 + A A 1 1 B 1 1 A 1 1 + 1 1 + A 1
Digitaria eriantha	+ 1 + + + + + r 1 + 1
Echinochloa holubii	+ r r r r r + +
SPECIES GROUP W	
Phragmites australis	1 + 1 + + 3 3 3 3 5 3
SPESIEGOEP X	
*Physalis viscosa**	+ 1 A + A 1 + + + 1 1 + 1 + + 1 1 A + A
SPECIES GROUP Y	
Schoenoplectus corymbosus	4

* = introduced species -
DW = declared weeds (Wells et al. 1986)

abundance are not included in the phytosociological table. These species are, however, included in Table 2 and are also mentioned in the results. An ordination algorithm, DECORANA (Hill 1979b), was also applied to the floristic data to determine vegetation gradients and to relate those to possible environmental and disturbance gradients. In addition, estimated height and canopy cover averages for the tree, shrub and herbaceous strata are given for each community (Table 3). Differentiation between trees and shrubs was based on definitions proposed by Edwards (1983).

Taxa names conform to those of Arnold and De Wet (1993), but are updated according to the PRECIS floristic data base of South Africa done in November 1996, managed by the National Botanical Institute in Pretoria. Declared invader and weed species were identified according to Wells *et al.* (1986).

Results and Discussion

Classification

From the classification nine communities, two subcommunities and three variants were recognised (Table 1):

1 *Setaria sphacelata–Themeda triandra* Community
  1.1 *Asparagus laricinus–Themeda triandra* Subcommunity
  1.2 *Senecio inornatus–Sesbania bispinosa* Subcommunity
    1.2.1 *Berkheya radula–Hyparrhenia hirta* Variant
    1.2.2 *Cyperus marginatus–Cynodon dactylon* Variant
    1.2.3 *Cirsium vulgare–Physalis viscosa* Variant
2 *Chamaesyce inaequilatera–Eragrostis trichophora* Community
3 *Panicum maximum–Salix babylonica* Community
4. *Sida rhombifolia–Eucalyptus camaldulensis* Community
5. *Tagetus minuta–Cynodon dactylon* Community
6. *Cyperus fastigiatus* Community
  6.1 *Paspalum distichum* Subcommunity
  6.2 *Gleditsia triacanthos* Subcommunity
7. *Typha capensis* Community
8. *Phragmites australis* Community
9. *Schoenoplectus corymbosus* Community

Description of the plant communities

Based on structure the vegetation clearly represents three types, namely grassland, woodland and marshy vegetation dominated by sedges. Except where explicitly indicated as exotic all species mentioned are indigenous.

1. *Setaria sphacelata–Themeda triandra* Community

The *Setaria sphacelata–Themeda triandra* Community represents a transition between wetland communities and adjacent grassland communities. The largest part of the flood plains of the Schoonspruit is covered by this transitional community. The community is situated on the flood plains (Figure 2), but may also occur directly alongside the river bank or may be separated from the riverbank by dense stands of woody vegetation.

The diagnostic species of this community, are the grasses *Themeda triandra*, *Setaria sphacelata* and the forb *Berkheya radula* (species group E, Table 1). The average cover of herbaceous species of this grassland community is the highest of all the communities in the study (Table 3). A relatively low average of 13 species per relevé was, however, encountered in this community.

A similar community, the *Themeda triandra–Eragrostis curvula* Wetland community, was described by Eckhardt *et al.* (1993) in the Vrede-Memel-Warden area in the Free-State. According to Eckhardt *et al.* (1993), the *Themeda triandra–Eragrostis curvula* Wetland community also occurs in flat bottomlands or floodplains next to rivers. The same species are found, namely *Themeda triandra*, *Setaria sphacelata* and *Senecio inornatus*.

Table 2 List of species which only occured a few times in the wetlands of the Klerksdorp Municipal Area, North West Province, South Africa

Species	Relevé (Cover)
COMMUNITY 1.1	
Cuscuta campestris	19 (+)
Enneapogon cenchroides	17 (r)
Falckia oblonga	33 (+)
Panicum dregeanum	52 (r)
Pennisetum clandestinum	19 (+)
Talinum arnotii	23 (r)
Tribulus terrestris	17 (+)
COMMUNITY 1.2.1	
Chironia palustris	48 (+)
Crabbea angustifolia	56 (+)
Haplocarpha scaposa	47 (1)
Juncus exsertus	48 (1)
Scirpus burkei	49 (+)
COMMUNITY 1.2.2	
Elephantorrhiza elephantina	7 (+)
Rhynchosia nervosa	42 (+)
Vernonia oligocephala	7 (+)
COMMUNITY 1.2.3	
*Achyranthus aspera**	15 (1)
Albuca sp.	55 (r)
COMMUNITY 2	
Leersia hexandra	26 (+)
COMMUNITY 4	
Carissa bispinosa	40 (r)
Euclea undulata	40 (r)
Taraxacum officinale	40 (r)
COMMUNITY 5	
Diospyros lycioides subsp. *lycioides*	1 (+)
Eragrostis superba	39 (r)
Eustachys paspaloides	39 (+)
Felicia muricata	44 (r)
*Lepidium bonariense**	1 (+)
*Melia azedarach**	1 (1)
Portulaca quadrifida	44 (r)
*Solanum nigrum**	1 (+)
Walafrida densiflora	44 (+)
COMMUNITY 6.1	
Becium angustifolium	28 (+)
Berula erecta	2 (+)
Convolvulus sagittatus	13 (+)
Echinochloa crus-galli	28 (+)
*Fraxinus americana**	22 (+)
Ranunculus multifidus	28 (r)
COMMUNITY 6.2	
*Bromus catharticus**	35 (+)
Sida dregei	35 (+)
Asclepias decipiens	42 (r); 50 (+)
Crotalaria virgulata	53 (+)
COMMUNITY 7	
Boophane disticha	18 (+)
COMMUNITY 8	
Stachys hyssopoides	11 (+)
NO SPECIFIC COMMUNITY	
Acacia karroo	52 (+); 32 (B); 3 (1); 34 (1)
*Amaranthus hybridus**	47 (r); 20 (1); 25 (1); 26 (+); 54 (1); 39 (+); 38 (+); 50 (+); 18 (+)
Aristida congesta	17 (+); 25 (r); 37 (+)
Asparagus africanus	1 (r); 16 (r); 23 (+);
Celtis africana	40 (+); 35 (1)
*Cichorium intybus**	13 (+); 15 (+); 16 (+); 17 (1); 39 (+)
Corchorus asplenifolius	42 (r); 41 (r)
Crinum bulbispermum	42 (r); 8 (+); 9 (1); 15 (r); 55 (+); 24 (r); 53 (r); 11 (r)
Marsilea capensis	43 (1); 44 (r)
Pentzia globosa	23 (+); 39(+)
Peucedanum magalismontanum	15 (+); 14 (r)
*Populus canescens**	52 (+); 7 (1); 8 (r); 55 (r); 54 (1); 1 (+); 3 (1); 53 (+); 10 (1)
Sida spinosa	54 (+); 50 (+)
Solanum panduriforme	23 (1); 34 (1); 11 (+)
Urochloa panicoides	52 (r); 32 (+); 39 (+)
Vigna vexillata	42 (r); 25 (r)

* Introduced species

The *Setaria sphacelata–Themeda triandra* Community represents the *Eragrostidetum planae* described by Bezuidenhout and Bredenkamp (1991) in the bottomland, seasonally wet areas of the Bc-land type in the western-Transvaal grassland. The *Eragrostidetum planae* occurs in a similar habitat than the *Setaria sphacelata–Themeda triandra* Community. Corresponding species are *Berkheya radula*, *Themeda triandra* and *Setaria sphacelata*.

Table 3 The stratification of the wetlands in the Klerksdorp Municipal Area, North West Province, South Africa

	Stratum					
	Trees		Shrubs		Herbs	
Community	Average height (m)	Average cover (%)	Average height (m)	Average cover (%)	Average height (m)	Average cover (%)
1.1	-	-	1.5	12	1	81
1.2.1	-	-	1.5	1.5	1	64
1.2.2	-	-	1.5	3.5	1	67
1.2.3	-	-	1.5	2.5	1	77
2	-	-	1.5	1.6	1	57
3	10	51	2	6.3	0.8	46
4	18	66	2	7	0.8	40
5	8	13	1.5	5	0.8	54
6.1	-	-	-	-	1.7	60
6.2	5	5	1.5	3.4	1.7	65
7	-	-	-	-	2	56
8	-	-	-	-	3	60
9	-	-	-	-	1.5	66

Two subcommunities, whose species composition changes as one moves away from the typical wetland area, can be distinguished. The similar transitional community described from the wetlands of Potchefstroom (Cilliers *et al.* 1998) is not as complex, with different subcommunities and variants, as in this study. This complexity could indicate a greater variety and intensity of disturbances of wetlands in the Klerksdorp Municipal Area.

1.1 *Asparagus laricinus–Themeda triandra* Subcommunity

This subcommunity is found in the drier parts of the *Setaria sphacelata–Themeda triandra* Community. The transition between wetlands and surrounding grasslands is quite evident when the differences in habitat and species composition of this subcommunity are compared with those of the other communities in the study. The dominant grass species are *Themeda triandra* and *Setaria sphacelata* (species group E, Table 1). A relatively abundant forb in this community is *Berkheya radula* (species group E, Table 1) which is characteristic of a moist, clayey grassland habitat. The soil structure varies from a clay loam to a sandy clay loam and mainly represents the Valsrivier soil form.

The only diagnostic species in this community is the grass *Sporobolus africanus* (species group A, Table 1), which is quite common in disturbed areas and along rivers (Van Oudtshoorn 1991). The dominant shrub in this community is *Asparagus laricinus* (species group R, Table 1), confirming the findings of Friedel (1987) that this shrub increases in disturbed woodland and grassland sites. Encroachment by *Asparagus laricinus* resulted in this subcommunity having the highest percentage shrub cover (Table 3) in the entire *Setaria sphacelata–Themeda triandra* Community.

Other species in this subcommunity include the forbs *Cichorium intybus* (exotic) and *Pentzia globosa* and the shrub *Asparagus africanus* (Table 2). An average of 13 species per relevé was found in this subcommunity of which 20% were annuals and 40% were exotics. Although only ocurring sporadically and with low cover abundance value, the declared weed *Cuscuta campestris* (Table 2) was identified in this community.

1.2 *Sesbania bispinosa–Setaria sphacelata* Subcommunity

The *Sesbania bispinosa–Setaria sphacelata* Subcommunity is found in the relative wetter parts of the *Setaria sphacelata–Themeda triandra* Community. Species diagnostic for this subcommunity are all forbs, namely *Senecio inornatus* and the exotic invaders *Sesbania bispinosa* and *Verbena bonariensis* (species group D, Table 1). Depending on the topographic position of this subcommunity in the wetland, three variants can be distinguished (Figure 2):

1.2.1 *Berkheya radula–Hyparrhenia hirta* Variant

The *Berkheya radula–Hyparrhenia hirta* Variant occurs at the water's edge where the embankment is not so steep. The habitat does change gradually from where the shallow water ends to the highest level where standing water is found during floods in the rainy season (Figure 2). The soil moisture level is quite high because of the shallow water table and the high clay content (52%) of the soil. The Katspruit soil form is mostly associated with this variant. No woody species are found in this area and the diagnostic species are *Hyparrhenia hirta*, *Rhynchosia totta*, *Xysmalobium undulatum* and *Arundo donax* (exotic) (species group B, Table 1). An average of 12 species per relevé were recorded in this variant of which 11% were annuals and 36% were exotic species.

1.2.2 *Cyperus marginatus–Cynodon dactylon* Variant

This variant occurs in areas of the *Sesbania bispinosa–Setaria sphacelata* Subcommunity where vertic soil of the Rensburg soil form is present. This soil has a high clay content (60%) with resulting high soil moisture.

Although no diagnostic species are present in this variant it is characterised by the presence of the highly invasive grass *Cynodon dactylon* (species group V, Table 1) and the sedge *Cyperus marginatus* (species group G, Table 1), as well as the

absence of species groups B and C (Table 1). The geophytes *Anthericum cooperi* (species group G, Table 1) and *Crinum bulbispermum* (Table 2) are also abundant in this variant. Other species occurring regularly are the common species of the study area (species groups R and V, Table 1) and the species commonly found in the grassland community (species group E, Table 1). A relatively low number of only 13 species per relevé were found in this variant of which 23% were annuals and 34% were exotic species.

1.2.3 *Cirsium vulgare–Physalis viscosa* Variant

The *Cirsium vulgare–Physalis viscosa* Variant of the *Sesbania bispinosa–Setaria sphacelata* Subcommunity develops in areas where water stagnate for short periods during the rainy season. The water level rises dramatically after heavy rains in the catchment areas of the Schoonspruit. After the water has receded small depressions remain in which water is stagnating in parts of the flood plains (Figure 2). The depositing of sediments, when these areas dry up after the rainy season, results in the formation of a thick A-horizon (40 cm) with a high sand content (52%). The resulting soil form is mainly Katspruit.

The dominant species is *Physalis viscosa* (exotic) (species group X, Table 1). *Cirsium vulgare* (exotic), which is a declared weed, *Panicum coloratum*, and *Conyza podocephala* (species group C, Table 1) are the diagnostic species for the variant. The presence of exotic invasive species like *Physalis viscosa* and *Cirsium vulgare* (declared weed) is the result of disturbances caused by the annual floods in this community. An average of 14 species per relevé, which is higher than elsewhere in the grassland community, were present in this variant, of which 19 were annuals and 29% were exotic species.

The *Cirsium vulgare–Physalis viscosa* Variant resembles the *Cirsio vulgaris-Eragrostidetum planae* described by Bezuidenhout *et al.* (1993) in the Bd land type. Some of the corresponding species are the forbs *Cirsium vulgare*, *Conyza podocephala* and *Berkheya radula* as well as the prominent grasses *Themeda triandra*, *Setaria sphacelata* and *Panicum coloratum*.

2. *Chamaesyce inaequilatera–Eragrostis trichophora* Community

This community has a widespread occurrence in the study area. It is found on the sloping edges of the depressions in which water stagnation occurs seasonally, as described for the *Cirsium vulgare–Physalis viscosa* Variant (1.2.3) (Figure 2). It occurs mainly on the clayey loam soil of the Valsrivier soil form. Although the clay content of the soil is high enough to restrict the water penetration to a certain extent, waterlogging is not so evident in this community. This could be due to the sloping terrain on the edges of waterlogged areas (Figure 2). Diagnostic species of the community include the grass *Eragrostis trichophora*, the forb *Chamaesyce inaequilatera* and the sedge *Cyperus rupestris* (species group F, Table 1). The grass species *Leersia hexandra* (Table 2) is also found in some parts of the community. An average of 13 species per relevé were recorded in this community of which 27% were annuals and 20% were exotic species.

3. *Panicum maximum–Salix babylonica* Community

The only diagnostic and also dominant species in this community is *Salix babylonica* (species group H, Table 1), an exotic tree which can be regarded as naturalised in South Africa (Henderson 1991). *Salix babylonica* is found in dense stands all along the Schoonspruit. Communities in which this species is dominant have also been described elsewhere in the Grassland Biome (Eckhardt *et al.* 1993; Cilliers *et al.* 1998). Due to the fact that *Salix babylonica* is mainly distributed by means of vegetative reproduction of water transported branches, this community established mainly alongside water courses (Figure 2). It is, however, not restricted to specific soil conditions and is found on various soil forms.

The large diameter of the crowns of *Salix babylonica* resulted in a specific microhabitat underneath the trees where a number of other species can establish. Some common species found in this community are *Panicum maximum*, *Asparagus laricinus* and *Bidens bipinnata* (exotic), (species groups L & R, Table 1). A high cover value is found in both the tree-(51 %) and herbaceous strata (46%) (Table 3). The average number of species per relevé in the community were 15 of which 15% were annuals and 48% were exotic species.

4. *Sida rhombifolia–Eucalyptus camaldulensis* Community

The vegetation of this community is associated with the habitat found under dense stands of the exotic planted tree *Eucalyptus camaldulensis* (species group I, Table 1) which is one of the diagnostic, but also the dominant species in this community. The vegetation in this community is stratified resulting in a high total cover (Table 3). The *Sida rhombifolia–Eucalyptus camaldulensis* Community is mostly found on melanic clayey soils (43% clay) of the Willowbrook soil form of which the A-horizon is deeper than 1.5 m in some places.

Other diagnostic species of this community are *Asparagus suaveolens*, *Bidens pilosa* (exotic) and *Ruta graveolens* (exotic) (species group I, Table 1). Although *Sida rhombifolia* (species group K, Table 1) is not diagnostic for this community, it has a higher cover than in the *Tagetus minuta–Cynodon dactylon* Community (5). An average of 22 species per relevé were recorded in the community of which 21% were annuals and 38% were exotic species. The higher species richness may be the result of the establishment of *Eucalyptus camaldulensis* plantations in the past. Many trees, especially *Eucalyptus camaldulensis* were planted for their wood (Poynton 1968) and have established well especially along the banks of the Schoonspruit (Figure 2).

Another community in which *Eucalyptus camaldulensis* is dominant was described in the urban open spaces of Potchefstroom, namely the *Eucalyptus camaldulensis–Melia azedarach* Community (Cilliers 1998). These two communities do, however, differ considerably from each other with respect to habitat and species composition.

5. *Tagetus minuta–Cynodon dactylon* Community

Although this community also has some woody vegetation, it differs from the *Sida rhombifolia-Eucalyptus camaldulensis* Community. The diagnostic species of this community are those of species group J (Table 1). The tree stratum consists of a variety of tree species that do not reach the same height as *Eucalyptus camaldulensis* (Table 3). Woody species occurring sporadically are the trees *Rhus lancea* (species group J, Table 1), *Ziziphus mucronata* subsp. *mucronata* (species group K, Table 1) and *Acacia karroo* (Table 2), shrubs like *Diospyros lycioides* subsp. *lycioides* (Table 2), *Rhus pyroides* (species group Q, Table 1) and *Maytenus heterophylla* (species group N, Table 1) and the exotic invader species *Melia azedarach* (Table 2). The dominant species in the community are, however, the grass *Cynodon dactylon* (species group T, Table 1), the forb *Tagetus minuta* (exotic) (species group U, Table 1) and the shrub *Asparagus laricinus* (species group R, Table 1). Other species found in the community are *Panicum maximum* (species group L, Table 1) and *Conyza bonariensis* (exotic) (species group Q, Table 1). An average of 19 species per relevé were recorded in the community of which 24% were annuals and 43% were exotic species. The species composition suggests severe disturbance and changes from the natural vegetation.

6. *Cyperus fastigiatus* Community

The *Cyperus fastigiatus* Community develops on the bank of the river close to the edge of the water or in shallow water (Figure 2), and is able to occupy relative large areas in short periods of time. This community is characterised by species group P (Table 1) which includes the dominant species, the sedge *Cyperus fastigiatus*.

The distribution of this community is not limited to a specific habitat in the wetlands, but is found in a mosaic pattern with the *Panicum maximum–Salix babylonica* Community (3), *Sida rhombifolia–Eucalyptus camaldulensis* Community(4), *Tagetus minuta–Cynodon dactylon* Community (5), *Typha capensis* Community (7) and *Phragmites australis* Community (8). To a certain extent this community is limited, however, to the Katspruit soil form. Because of the depositing of sediments when seasonally wet areas dry out there is a high percentage of sand (± 60%) present in the upper layers of the soil. Two declared exotic weeds, namely *Sesbania punicea* and *Xanthium strumarium* occurred in 50% of the sample plots in this community.

Two subcommunities are distinguished depending on their location in or adjacent to the water.

6.1 *Paspalum distichum* Subcommunity

The *Paspalum distichum* Subcommunity is found in waterlogged areas where the soil surface is partly or entirely covered with water. *Paspalum distichum* (species group M, Table 1) grows in dense stands of *Cyperus fastigiatus* (species group P, Table 1). This observation is in accordance with Louw (1951) who found that *Paspalum distichum* creeps from the riverbank into the water to form a floating platform of grass.

The diagnostic species of this subcommunity are those of species group M (Table 1). Another species found in the community is the floating water fern *Azolla filiculoides* (exotic) (species group M, Table 1), which is an aggressive invader of watermasses in South Africa (Henderson 1995). This subcommunity is found in shallow, seasonally waterlogged areas where fairly pure stands of *Cyperus fastigiatus* are found. Disturbance of the wetland leads to the invasion of species such as the exotic forbs *Chenopodium album* and *Verbena officinalis* (species group M, Table 1) into this subcommunity. An average number of 17 species were found per relevé of which 27% were annuals and 42% were exotic species.

6.2 *Gleditsia triacanthos* Subcommunity

This subcommunity establishes in dense stands in disturbed areas along the Schoonspruit. The diagnostic species include the exotic invasive tree *Gleditsia triacanthos* (species group O, Table 1). Disturbances due to seasonal flooding of the area occupied by the *Cyperus fastigiatus* Community results in the increase of pioneer species like *Urochloa mosambicensis* (species group M, Table 1). The existing disturbance is mainly because of the building and maintenance of a bridge over the Schoonspruit. Other invasive exotic species include *Conyza bonariensis*, *Chenopodium album* and *Plantago lanceolata* (species group Q, Table 1). In this subcommunity an average of 15 species were found per relevé of which 23% were annuals and 43% were exotic species.

7. *Typha capensis* Community

In this community dense stands of *Typha capensis* (species group S, Table 1) growing in standing water or seasonally drier areas are found (Figure 2). Other species found among the stands of *Typha capensis* are the creeping grass *Stenotaphrum secundatum* (species group S, Table 1) which is together with *Typha capensis* diagnostic for this community, and the water fern *Marsilea capensis* (Table 2). Other species found in the community are *Tagetus minuta* (exotic) (species group U, Table 1) and *Cynodon dactylon* (species group V, Table 1).

This community is mostly found on Katspruit or Champagne soil forms. An increase in abundance of *Typha capensis* in the Schoonspruit results in water stagnation. Water stagnation has relevance to an assortment of pests found in the river because it serves as a breeding-ground for mosquitoes and Bilharzia-snails (Bromilow 1995). The species richness of this community is relatively low and an average of only 12 species per relevé were found of which 32% were annuals and 53% were exotic species.

A similar community, the *Typha capensis* Reedswamp Community, was described in the Potchefstroom Municipal Area as a pioneer in reedswamp succession (Cilliers *et al.* 1998).

8. *Phragmites australis* Community

Phragmites australis (species group W, Table 1), the only diagnostic species found in this community, is not only found in standing water but also on dry riverbanks during dry seasons (Figure 2). During these drier conditions other species like the exotics, *Bidens bipinnata* (species group R, Table 1) and *Physalis viscosa* (species group X, Table 1) are also found in the community. The community is often found as pure stands of *Phragmites australis* with little other species present. Marks *et al.* (1994) describes *Phragmites australis* as a species with the ability to invade large areas of wetlands. It is even found in standing water to a depth of two meters and causes problems similar to those found in the *Typha capensis* community. The water stagnation in this community also caused the depositing of sediments forming huge sandbanks in the community. This results in the soil of this community consisting of a high percentage sand (> 60%). The *Phragmites australis* Community is usually found on Katspruit and Valsrivier soil forms. The species richness found in this community is relatively low in comparison with the *Typha capensis* Community consisting of an average of only 5 species per relevé of which 28% were annuals and 53% were exotic species.

Similar communities were described in the North-eastern Sandy Highveld (Bloem *et al.* 1993) and the Potchefstroom Municipal Area (Cilliers *et al.* 1998). Communities in which *Phragmites australis* dominates also occur in fresh-water and brackish swamps in Europe (Mucina 1997) and all these communities (included those in South Africa) belong to the class *Phragmito–Magnocaricetea* Klika in Klika et Novák 1948. It is possible, however, that the *Phragmites australis* Communities in South Africa belong to a new order of this class (Cilliers 1998).

9. *Schoenoplectus corymbosus* Community

This community almost always consists of only *Schoenoplectus corymbosus* (species group Y, Table 1). The only exception being *Paspalum distichum* (species group M, Table 1) creeping into the water among *Schoenoplectus corymbosus*. *Schoenoplectus corymbosus* has several sturdy, upright stems growing out of a perennial rhizome anchored on the river-bed. It is found as pure dense stands in standing water (Figure 2). The deep soil (> 1.2 m) on which it grows is representative of the Champagne soil form. The species richness is low with rarely more than one species per relevé. A similar community was described in the urban wetlands of Potchefstroom (Cilliers *et al.* 1998).

Ordination

In Figure 3 the distribution of all the relevés along the first and second ordination axes is given. The plant communities are clearly limited to certain positions in the scatter diagram. The diagram illustrates a gradient along ordination axis 1 which could be related to vegetation structure. Grasslands are situated at the left of the scatter diagram, with woodlands in the centre and shrublands and sedgelands to the right of the diagram. The

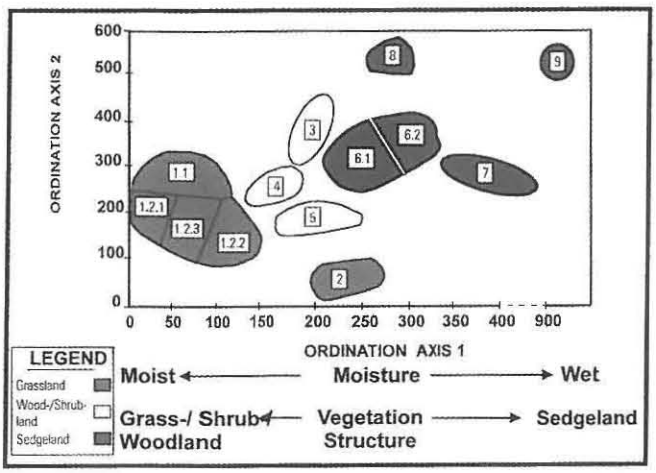

Figure 3 The relative positions of all the relevés along the first two axes of the ordination of the wetlands in the Klerksdorp Municipal Area, North West Province, South Africa (numbers refer to those in text).

Chamaesyce inaequilatera–Eragrostis trichophora Community (Figure 3, community 2), found in the centre of the vegetation structure gradient, is a grassland with a high percentage of sedges. Also present along ordination axis 1 is a moisture gradient from high at the left to very high (water saturated soil) to the right, where standing water is found. The *Typha capensis* community (Figure 3, community 7) is often found in water, but sometimes also on drier riverbanks especially during drier seasons. The *Schoenoplectus corymbosus* community (Figure 3, community 9), seen on the right-hand side of the scatter diagram, is always found in standing water.

The gradient along ordination axis 2 could be related to the dominance of one or more species in the communities. The communities found at the bottom of the scatter diagram are dominated by a number of species and many diagnostic species add to the species diversity of the community. In the communities at the top of the diagram, however, one species normally dominates the community to such an extent that these communities are almost monospesific. Although the species diversity of the communities at the top of the diagram is lower than that of the communities at the bottom of the diagram, the gradient along ordination axis 1 cannot be related to species diversity at such.

Conclusion

Characteristically of wetlands, clearly distinguishable plant communities with exact boundaries can be distinguised. This is typical of studies done previously in wetlands of the Grassland biome (Cilliers *et al.* 1998; Eckhardt *et al.* 1993; Fuls *et al.* 1992; Kooij *et al.* 1991). The distribution of most of the communities is closely associated with differences in topography, like the position of plant communities on flat, sloping or undulating areas in the wetlands (Figure 2). The distribution of the plant communities also depends, however, on changes in habitat conditions like the amount of moisture present (Figure 3). Disturbance, resulting from direct or indirect human impacts, further caused the development of specific plant communities. Communities like the *Sida rhombifolia–Eucalyptus camaldulensis* (4) and *Panicum maximum–Salix babylonica* (3) Communities are highly invasive and do not seem to have much correlation with habitat factors such as topography, soil type and soil depth. These communities invade any disturbed habitat in wetlands, replacing the original vegetation. Although most of the communities are situated on specific soil types, specific soil characteristics determined by physical and chemical analyses appear to have little affect on the distribution of most of the plant communities.

Soils of wetlands are often affected, mainly due to the occurence of seasonal floods. Combined with consistent human disturbance this results in serious degradation of vegetation in some of the communities. The occurence of these communities are especially limited to residential, industrial and central commercial areas.

The influence of the surounding urban environment enhances the species richness of the wetlands of the study area. The presence of species such as *Eucalyptus camaldulensis* forms unique microhabitats in wetlands, which favour certain introduced annual species. Other communities, like the *Phragmites australis* Community, often have the ability to invade and destroy large areas of existing plant communities.

The high levels of disturbance can clearly be seen from the high percentage of introduced species present in most of the plant communities (Tables 1 and 2). Although these disturbances resulted in a higher species richness, the invasive ability of many of these species unavoidably leads to decreasing of the number of natural species. It is important to manage these invasive communities in such a way that expansion and spread into other communities is prevented. The presence of 4 declared weed species, *Cirsium vulgare, Cuscuta campestris, Seshania punicea* and *Xanthium strumarium* confirmed the neglect shown by municipal authorities towards wetlands.

Information on the existing communities and species in these wetlands can serve as a basis for the compilation of a conservation orientated management program, which includes certain restoration practices, for the wetlands of Klerksdorp. Successful salvage or restoration of disturbed wetlands can only be reached if specific stresses are removed and hydrological connections relinked (Cairns & Heckman 1996). According to Doust and Doust (1995) wetland management should be aimed at habitat and species conservation so that presence of rare species can be used as symbols of site recovery whereas their absence can be used as evidence of impairment. Much more research is needed on wetlands in South Africa to determine amongst others the vegetation dynamics and the extent of any rare species. This is, of course, also true for the rare species of other habitats, but the exponential rate of loss of wetland to development and increasing intensity of stakeholder pressures on remaining wetlands, made the wetland issues more urgent (Doust & Doust 1995).

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